

ECOLOGICAL EFFECTS OF RABBIT REDUCTION ON RABBIT ISLAND, WILSONS PROMONTORY, VICTORIA

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Abstract

With reduction of rabbits on Rabbit Island, Wilsons Promontory, Victoria, an increase in vegetation and changes in the muttonbird rookery distribution occurred. A previously eroded area became colonized by plants, and by rookeries of *Puffinus tenuirostris*.

During the three-year study period a previously eroded area of 16 acres of blown sand was recolonized, and the eroded area reduced to 1.5 acres. A succession of plant communities occurred in which annuals were replaced by perennial tussocks of *Poa poiformis*. Nesting *Puffinus tenuirostris* entered the sequence during this process. It is postulated that the centre of the island will revert to shrubby communities with a peripheral grassland containing muttonbird and penguin rookeries.

Introduction

The introduction of rabbits is well known to result in modification to the ecosystem; this impact is often particularly marked on islands. Watson (1961b) gave details of an extreme example where, on two Pacific islands (Lisianski and Laysan), vegetation was completely removed by rabbits. On Laysan Island this resulted in the extinction of two bird species and one subspecies, and eventually of the rabbits themselves. It was only then that the vegetation recovered to the extent that albatrosses returned to nest (Bailey 1956). Similar sequences of events have been recorded for Phillip Island, in the Hawaiian Group (Watson 1961a), and for Smith Island, near Washington, U.S.A. (Couch 1929).

Gillham (1955) recognized the importance of rabbit grazing on Pembroke (U.K.) islands. She demonstrated that the flora was modified both by wind and grazing, the latter the more important factor. Inhibition of plant growth may also occur as the result of trampling and burrowing (Gillham 1956). Burrowing, according to Gillham, has three main effects, viz.:

- (a) direct effect in exposing parts normally buried, and burying parts normally exposed
- (b) initiation of wind and water erosion
- (c) alteration of atmospheric conditions below ground.

At the same time, she stated that any disturbance of the soil appears to attract rabbit attention. Because of this, any community once disturbed is more likely to be further disturbed, so that burrowing becomes an important initiator of erosion by wind.

Rabbits have been held responsible for soil erosion on Macquarie Island (Carrick & Costin 1959). In rabbit-grazed areas vegetation showed graduations to bare areas where soil had been removed by erosion. On steeper slopes soil slip occurred, and in herbfield regions seedling germination was restricted with the result that some plant species were slowly disappearing from the communities.

Costin and Moore (1960) thought that the ecosystem on Macquarie Island, with a small number of plant species, was less stable than others containing a higher total number and they considered that there was no buffer species present to offset the selective rabbit grazing. Rabbit grazing, according to Holdgate and Wace (1961), caused the breakup of a community of 23 species and led to widespread erosion when directed at the dominant *Poa foliosa*. They later showed that reduction of plant communities on the Iles Kerguelen had resulted in the restriction of previous dominant species to rabbit-free islets and cliffs.

Rabbits were introduced to several Bass Strait islands as a potential food source. This occurred on Citadel Island, six miles off the western side of Wilsons Promontory. Comparison of a photograph taken there in 1913 (made available by the Director of Lighthouses, Commonwealth Department of Shipping and Transport) with a later description of the island (Gillham 1961) indicates that the vegetation was reduced in this period. Now *Poa* tussock is almost completely absent and the few muttonbirds, *Puffinus tenuirostris* Temmick, breeding on the island utilize rock crevices (Dr D. F. Dorward, pers. comm.).

The rabbit, then, is the cause of considerable desolation on islands where the simplified ecosystem, developed in the absence of herbivores, has no resistant buffering species of plant. Modification, and sometimes destruction of the native vegetation adversely affects the bird species which may have utilized the vegetation, or the soil beneath it. Since local declines of muttonbird populations have been attributed to introduced mammals, Rabbit Island offered an opportunity to study the effects of the rabbit on the muttonbird. Accordingly a programme was initiated there in 1965.

The Programme on Rabbit Island

Rabbits were introduced on to Rabbit Island in 1836 (Stokes 1846) as a food source for shipwrecked persons. Since that time erosion of soil, due to the removal of vegetation, has led to a sand blow across the centre of the island. This was first noted in the literature by Gillham (1961) and she also observed that the eroded area contained the remains of an extensive muttonbird rookery.

It was decided to examine the effects of erosion, including the rabbit's participation in erosive processes, on muttonbird rookeries on the island. Elimination of the rabbit population would, it was hoped, halt the erosion and enable the eroded areas to become vegetated to the extent that rookery areas might increase.

METHODS

During the period May 1965 to September 1968, nine visits were made to the island. In May and October 1965, the distribution of the various plant species was noted and a simplified vegetational map made. New species found on later visits were also recorded.

A trigonometric survey point, present on the island's summit, was used as a base mark for surveying the sand blow. By using a chain and prismatic compass, the position of stakes around the edge of the sand blow were determined and plotted on a plan of the area. Measurement from these numbered stakes towards the centre of the blow enabled accurate limits of two *Senecio lautus* zones to be determined. Changes in the eroded area were observed by using the stakes as markers on succeeding visits. The blow was surveyed again in August 1966.

Line transects, to indicate vegetational changes during the study, were taken along two routes. The first was from the southern end of the sand beach on the western side of the island; the second was taken across the eroded area, from a

peg fixed in position in August 1966, to the trigonometric point. In both transects, cover by each species was estimated for intervals of ten feet and expressed as a percentage.

To gather evidence of any change in the distribution of muttonbird burrows following the removal of rabbits, rookery distribution was determined on the first visit, during the 1964-65 breeding season. Observations were also made in December 1967 and June 1968, after the 1967-68 breeding season, and again in September 1968 after the start of the 1968-69 season. In the latter visit, transects were taken across the sand blow and counts made of the burrow entrances encountered. Since in the 1964-65 breeding season the burrow limit was equivalent to the *Poa* boundaries, this enabled a measure of the change in rookery distribution to be made.

An indication of burrow stability under various vegetation-sand combinations was gained in March 1966. During this visit, transects were taken through portions of rookeries in three main categories, viz. pure sand, sand partially (less than 50 per cent) colonized by *Poa poiformis* and *Carduus tenuifloris*, and in pure *P. poiformis*. The burrows touching the transect line were counted and the ratio of collapsed to non-collapsed burrows used as a measure of burrow stability in each particular situation.

Though it was hoped to start the programme with a relatively large rabbit population, myxomatosis had removed the majority of the population by the time of the first visit (May 1965). It was obvious that poisoning would have to be used as a control measure for the remaining animals and I am grateful to Mr G. W. Douglas of the Vermin and Noxious Weeds Destruction Board for arranging this. The island was first poisoned in January 1966 with sodium fluoroacetate-impregnated carrot pieces (standard '1080' poisoning). The small carrot pieces were distributed around the summit on this and on later visits since the majority of droppings were found in this area. Bait was also scattered wherever signs (droppings, scratch-marks or freshly grazed plants) appeared on the northern or southern end of the island. Poisoning was carried out in March and August 1966 and March and December 1967 on the 'one-shot' basis (see Gooding 1961 for details).

RESULTS

The vegetation and physical features of Rabbit Island as found in 1965 have been recorded earlier (Norman 1967). The botanical changes following rabbit reduction had a profound effect on muttonbird distribution and are presented below, with particular reference to the changes which occurred over the main study area, the sand blow. Changes in the rabbit population, as reflected by relative indices, are presented prior to discussion of changes in rookery area which followed the increasing stabilization in the eroded area.

1. Changes in the Rabbit Population

During the study period no live rabbit was seen on the island. (All visits were during daylight hours.) Approximately 150 corpses were present in May 1965. Fresh droppings and scratch marks, together with grazed plants, were then found around the summit. Few traces were observed during the remainder of the programme and these, mainly droppings and fresh scratches, have been summarized in Table 1. The table gives an indication of the observable activity of the island rabbit population and may be considered as an index of total population size. After myxomatosis, damage to plants decreased and has remained at a low level

during the study. Indeed in 1968, it was not possible to find plants which had been grazed; fresh droppings were few (three locations in June and none in September) and scratch marks were found once in June.

TABLE 1
Summary of observations on rabbit activity

+++ = maximum for study period, ++ = moderate, + = traces, * = poison laid

Date	Poison	Scratch marks	Fresh droppings	Grazed plants	Comments
May 1965	—	+++	+++	++	c. 150 corpses
October	—	++	—	+	
January 1966	*	+	+	+	1 fresh corpse
March	*	+	+	+	
August	*	+	+	+	
March 1967	*	+	+	—	
December	*	+	+	—	
June 1968	—	+	+	—	
September	—	—	—	—	

2. Changes in the Island's Vegetation

(a) THE MAIN SAND BLOW AREA

In May 1965 the extent of the eroded area was surveyed and the boundaries mapped (Fig. 1). At this time the sand blow covered 16 acres, i.e. 20 per cent of the total 80 acres. *Poa* tussock bounded the area, with large belts of *Senecio* along the northern and southern edges. The island's summit was almost devoid of vegetation though occasional clumps of *S. laetus* extended into the bare area. A new growth of *P. poiformis* appeared at the southern edge of the blow in March 1966, when an increase in *Juncus pallidus* was noted.

The situation had changed by the time of the August 1966 visit. Whilst the course of the sand blow had ceased to be a dominant feature of the island, it was still discernible. Only at two sites were there areas of completely bare sand; these were surveyed (Fig. 2) and found to occupy 1.5 acres. *Senecio* communities, present on the earlier visits (Fig. 1), were generally decreased, with *Poa* replacing them. By March 1967 the eroded western area was still present but by December 1967 this became vegetated. Large communities of *Carduus tenuifloris* and *Poa* had colonized the site on the eastern side, *Poa* had spread across the blow and was found up to the summit. Occasional *Juncus* communities had increased up the slope and some 20 *Acacia longifolia* and 3 *Olearea axillaris* seedlings were found in the blow region.

The gross changes in vegetation across the sand blow region are indicated by transects shown in Fig. 3-7. These line transects were made along the same route, from a fixed peg to the trigonometric survey point, in August 1966, March and December 1967, and June and September 1968 respectively. The changes in importance of several species, and extent of bare earth, are given in Table 2 which shows the total cover of each species over the whole transect route. Cover was determined by line intercept and expressed for each species as a percentage of the transect length. Pl. 23 (top) shows the general increase in vegetation over the previously eroded region and this should be compared with Pl. 35 in Norman 1967.

Two other comparative transects were made, shown here as Fig. 8, and as



FIG. 1—The sand blow area as surveyed in March 1965. The trigonometric survey point, which is in the blow, is indicated by a small solid triangle. The limits of *Poa poiformis* are shown by the solid line whilst the interrupted line shows the *Senecio lautus* belt.



FIG. 2—The sand blow as surveyed in August 1966. Symbols as in Fig. 1.

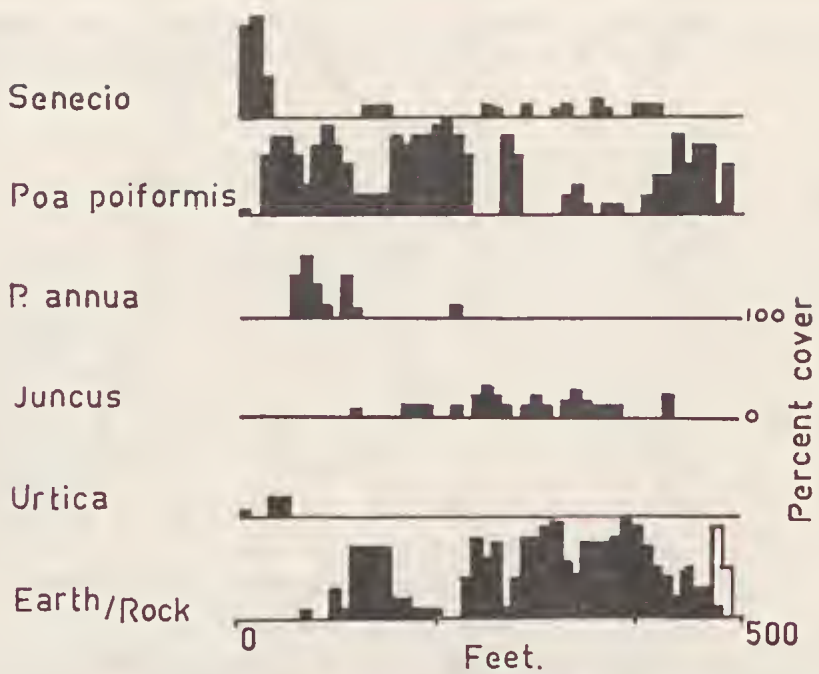


FIG. 3—Line transect from fixed peg to the trigonometric point at 175°; 490 ft long with intervals of ten ft. August 1966.

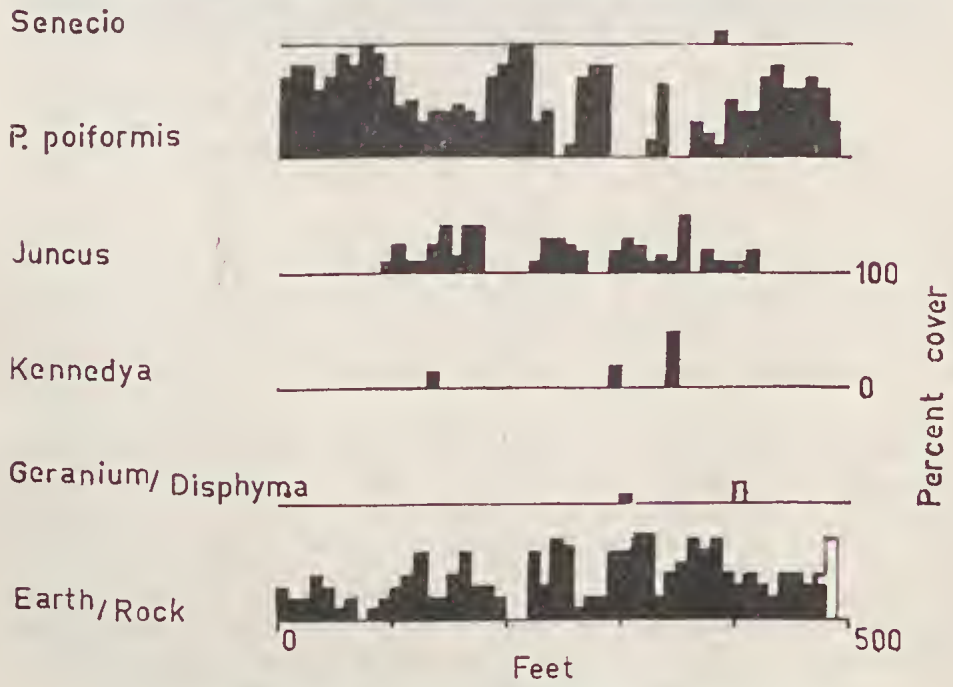


FIG. 4—Line transect from fixed peg to trigonometric point. March 1967.

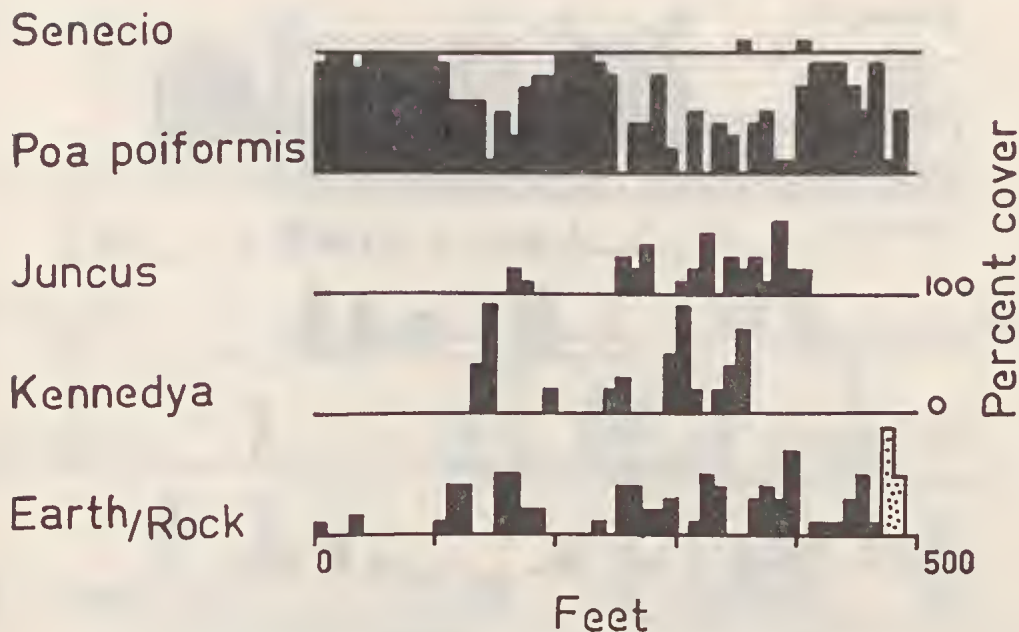


FIG. 5—Line transect from fixed peg to trigonometric point. December 1967.

Fig. 2 in Norman 1967. The difference in transect length is the result of a slight difference (less than $\frac{1}{2}^\circ$) in angle and also to the alteration in structure of the sand beach. From these two transects it can be seen that plant cover has increased, with a corresponding decrease in bare areas of sand. Representation of *P. poiformis* has increased markedly, from 41 per cent of the total transect cover to 61 per cent, whilst *Juncus* showed an initial increase from 5.4 to 16 per cent, then a decrease to 2.9 per cent.

In summary, the eroded area became sparsely colonized with ephemerals and annual grasses such as *P. annua*. In the absence of rabbit grazing a succession developed and, following *Senecio*, *P. poiformis* rapidly spread across the blow. This colonization led to a corresponding decrease in areas of bare sand. During

TABLE 2

Changes in the sand blow vegetation: total cover afforded by major species along the standard transect route as a percentage of the total cover

	1966	1967		1968	
	August %	March %	December %	June %	September %
<i>P. poiformis</i>	40.8	50.4	60.4	69.6	61.0
<i>S. laetus</i>	8.3	0.01	0.4	1.6	2.4
<i>J. pallidus</i>	5.4	16.0	7.9	5.1	2.9
<i>K. prostrata</i>	0.2	1.6	10.0	14.7	16.9
Earth/sand	42.2	36.2	19.4	7.9	15.4

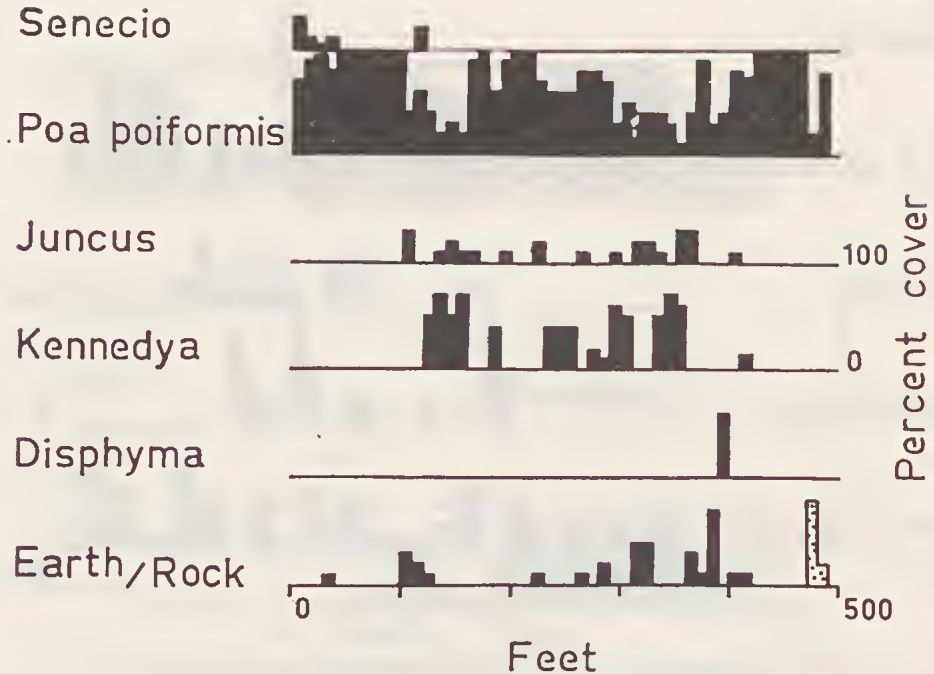


FIG. 6—Line transect from fixed peg to trigonometric point, June 1968.

this time, low prostrate species such as *Kennedyya* and *Carpobrotus* aided in the stabilization process and formed large communities which were still present at the end of the study. *Cotula australis* and *Urtica urens*, species which were widespread in August 1966, gradually disappeared after this time though *Pelargonium australe*, which had also been well distributed, remained in small clumps.

(b) ROOKERY TO THE SOUTH OF THE SAND BLOW

The portion of rookery vegetation bordering the southern end of the sand blow had, in March 1966, become almost flattened. *Poa* tussocks had dried out and stems had been broken off by birds, and probably wind, to become mixed with the bared soil. By August 1966 however, the bare area had become revegetated. *Senecio lautus* was the co-dominant species whilst fresh tussock and *Urtica urens* formed large communities. Within this area, small bare patches still occurred around burrows with *P. annua*, *Cotula australis*, *S. lautus* and *U. urens*. Occasional large clumps of *Solanum laciniatum* had appeared and were flowering; small communities of *Sonchus oleraceus* and *Carduus tenuifloris* were infrequently distributed throughout the area. A similar pattern of degeneration and destruction of rookery vegetation was noted during the two succeeding seasons. The restriction of seedling regrowth of *Poa annua* etc. in 1967-68 was probably due to the very dry year.

(c) THE BEACH REGION

The beach was backed by *Cakile maritima* and three individual *Atriplex hastata* bushes were present in May 1965. In August 1966, stream banks had been bared for some distance from the beach. Penguins were considered to be responsible for keeping down regeneration in the area and for continually disturbing the soil

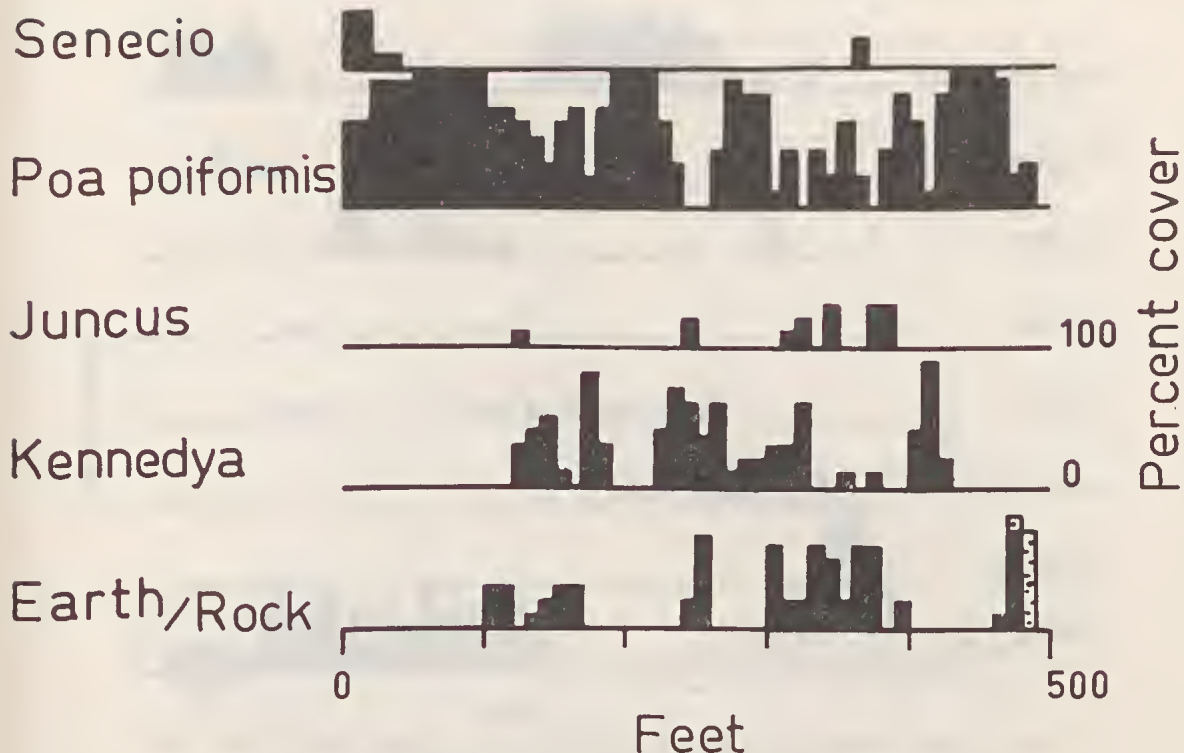


FIG. 7.—Line transect from fixed peg to trigonometric point. September 1968.

surface. The embryo dune system had been partially destroyed by August as the result of strong westerlies; these had also caused the formation of a wave bank higher up the beach. Large stems of *Atriplex* had been dislodged by wave action. The level ground, whilst still dominated by *Cakile*, showed much growth of *Atriplex* and *P. poiformis*. A dense community of marram grass, *Psamma* (= *Ammophila*) *arenaria* had appeared and spread up the hillside from the beach. By March 1967, the marram grass had covered approximately a third of the beach flat. By December 1967 it had spread slightly further up the hill, *Cakile* had almost disappeared and the *Atriplex* had slightly decreased. The wave bank had developed considerably by June 1968, in places reaching 3 ft. *Atriplex* was well developed along the central fore-region of the supra littoral zone, though marram grass had decreased and *Cakile* had been extensively replaced by *Tetragonia implexicoma*.

(d) THE TOTAL OF RECORDED PLANT SPECIES

In my earlier report I listed 35 vascular species, including nine aliens, which had been collected on Rabbit Island. Since then a further 11 have been recorded making the island total 46 (see Table 3 below). Gillham (1961) constructed a species:acreage ratio for several Promontory islands and for Rabbit Island the ratio was 1:3.75, with 24 plants recorded on the 90-acre island. This was a similar record to that for Clifty Island. Gillham considered that rabbits were depressing the total on Rabbit Island, making this island out of sequence in the

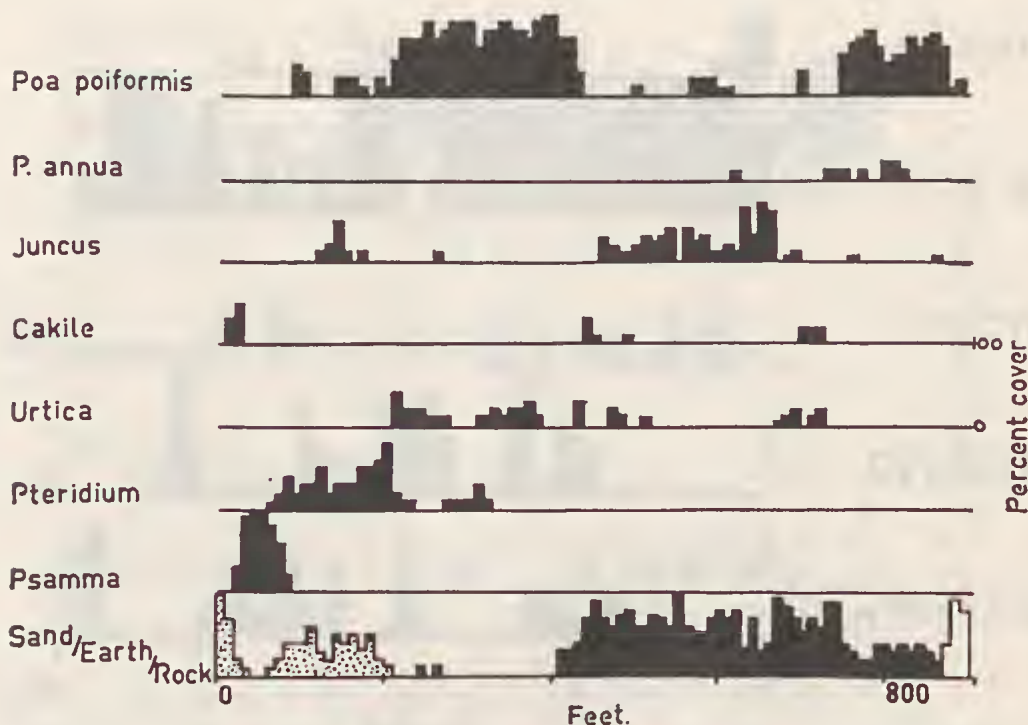


FIG. 8—Line transect from HWM on sand beach to trigonometric point (110°); 840 ft long with ten ft intervals. August 1966.

correlation of exposure and species:acreage ratios. Whilst the new total gives a ratio of about 1:1.8, and brings the island more into line with the series presented by Gillham, the increase in plants recorded may just reflect different collection times. Nevertheless, some species, such as *Kennedy*, have appeared on transect routes (Figs. 3, 5) and have increased in the absence of rabbits.

3. Changes in Muttonbird Rookery Distribution

In May 1965 the limits of muttonbird rookery were precisely those of the *Poa* tussock, which bordered the sand blow at that time. Whilst there were occasional burrows in the sand, the density was very low (much less than one burrow per 20 square yds). The rookery boundaries were therefore mapped out at the same time as the boundaries of the eroded area and the results are shown in Fig. 9, in which the occupied area has been separated into dense, occasional and rare.

In December 1967 the correlation between *Poa* and rookery was less definite and the boundaries, as estimated by eye, had moved in towards the centre of the old blow area. The two small eroded areas previously existing on the eastern and western side (August 1966) had become small rookeries after their colonization by plants. The central region was the only area lacking new burrows, though soil depth here was limited.

In September 1968, after the start of the 1968-69 breeding season, the sand blow area was surveyed using positioned transects. Burrow counts along these lines were measured at ten-foot intervals and boundaries thus determined were



FIG. 9—Estimated rookery distribution in May 1965; burrow concentration expressed as dense, occasional and rare.

joined to form Fig. 10. This clearly indicates the spread of rookery into the previously eroded area.

During the programme a measure of burrow stability was obtained by calculating the proportion of collapsed to open burrows in three main vegetation categories. In pure sand, only 50 burrows were counted and the ratio was 1:1; in sand partially stabilized with occasional *P. poiformis* and dead *C. tenuifloris* the ratio was again 1:1 ($n = 102$). In rookery under pure *P. poiformis* a ratio of 9:2 was obtained in favour of open burrows ($n = 111$).

Discussion

In May 1965 the flora of Rabbit Island was a restricted one dominated over most of the island by *Poa poiformis* (Norman 1967). At that time there was an extensive sand blow crossing the island from slightly above the western sand beach, across the summit and over to the eastern cliffs. The eroded area, which had once contained a muttonbird rookery, occupied 16 acres in May 1965 (Fig. 1). The line transects taken across the sand blow during the study (Fig. 3-6) indicate the considerable regeneration of vegetation which has taken place over the past three years. The decrease in eroded area (compare Fig. 1 & Fig. 2) had, by the end of the programme, continued to the extent that the 1.5 acres of bare sand present in

TABLE 3

Plant species recorded for Rabbit Island, Wilsons Promontory

<i>Pteridium esculentum</i>	<i>Crassula sieberiana</i>
<i>Microsorium diversifolium</i>	<i>Crassula helmsii</i>
<i>Asplenium obtusatum</i>	§ <i>Crassula</i> sp.
* <i>Vulpia bromoides</i>	§ <i>Acacia longifolia</i>
†* <i>Poa annua</i>	§ <i>Pultenaea daphnoides</i>
<i>Poa poliformis</i>	§ <i>Kennedya prostrata</i>
†* <i>Ammophila arenaria</i>	‡ <i>Pelargonium australe</i>
<i>Scirpus nodosus</i>	<i>Correa alba</i>
<i>Juncus pallidus</i>	<i>Leptospermum laevigatum</i>
<i>Dianella revoluta</i>	¶ <i>Lissanthe strigosa</i>
<i>Bulbine semibarbata</i>	<i>Cyathodes acerosa</i>
<i>Bulbine bulbosa</i>	† <i>Solanum laciniatum</i>
* <i>Urtica urens</i>	¶ <i>Wahlenbergia quadrifida</i>
<i>Muehlenbeckia adpressa</i>	<i>Lobelia alata</i>
† <i>Atriplex cinerea</i>	§* <i>Erigeron bonariensis</i>
* <i>Atriplex hastata</i>	<i>Olearia axillaris</i>
§ <i>Rhagodia baccata</i>	¶ <i>Helichrysum dendroides</i>
<i>Disphyma australe</i>	<i>Cotula australis</i>
<i>Carpobrotus rossii</i>	<i>Cotula coronopifolia</i>
† <i>Tetragonia tetragonoides</i>	<i>Senecio lantus</i>
<i>Calandrina calyptrata</i>	* <i>Carduus tenuifloris</i>
* <i>Stellaria media</i>	<i>Sonchus oleraceus</i>
* <i>Spergularia media</i>	
<i>Cakile maritima</i>	

* = introduced species; all others are native

† = March 1966

‡ = August 1966

¶ = December 1967

§ = June 1968, all others were collected in 1965 or recorded by Gillham (1961)

Island total = 46 vascular species; 9 alien species = 19.5%

August 1966 had become vegetated. Further evidence of the increase in ground cover by plants is given in Pl. 23 (top) and Fig. 7. During the programme, the reduction of the rabbit population, initially by myxomatosis and then by '1080' poison, is considered to be the only factor to have changed in favour of the vegetation. Indeed during 1967, a drought year in Victoria, the rainfall recorded for that area (at Wilsons Promontory lighthouse) was 15 inches less than the average of 40.9 inches. The decrease in observed rabbit activity has been summarized above, in Table 1.

The increase in vegetation has had a noticeable effect on the distribution of muttonbird burrows on the island (Figs. 9, 10). Whilst the birds have not completely colonized the blow area, the rookeries of the northern and southern edges have expanded into the area. The deeper sand on the eastern side above the cliffs has also become colonized. Burrows had increased in density on the western side after the 1966-67 breeding season and had appeared almost to the summit by the next season.

Elsewhere, several authors (e.g. Couch 1929; Watson 1961b) have shown that rabbits are capable of denuding island vegetations and seriously affecting the nesting species of birds which were utilizing the habitat. On Rabbit Island I suggested that removal of vegetation across the central portion led to the collapse of burrows and eventually to the decrease of rookery in the area (Norman 1967). It seems probable however that the destruction across the central region was secondary to the removal of scrub cover in the region. Then *Poa*, and later birds,



FIG. 10—Rookery distribution in 1965 and 1968. Outline of sand blow in 1965 (which corresponded to rookery limits) is shown; distribution in 1968 estimated from transects taken across the previously eroded area. (Transect routes shown as and presence of burrow by o . . o.)

invaded the area. Erosion followed after the establishment of the tussock and it is this latter stage, the effect of rabbits on a *Poa*-dominated rookery, which will be considered further.

Gillham (1961) considered that drought, birds and rabbit grazing were the main cause of the relatively uniform, poor flora of the island. She thought (Gillham 1962) that an equilibrium was set up between plants and rabbits, each limiting the other in a dry season such as 1959 (and indeed 1967). *Poa* shoots were, she considered, the only source of food utilized. Results obtained during this present study show that the rabbit population must have been responsible for the suppression of species such as *Kennedyia* and the prevention of maturation of seedling scrub species. Birds are also responsible for partial destruction of rookery floras (Gillham 1961 a & b). Norman (1967) gave some evidence that localized erosion was caused on the island by penguins and muttonbirds. Tracks on the western side, from the sand beach, are kept open by penguins moving in and out of nesting areas (Pl. 23, bottom). The muttonbird, on the other hand, is responsible for damage and destruction of tussock during its breeding season. This was particularly noticeable along the western side where the earth was almost devoid of cover in

the 1966-67 and 1967-68 breeding seasons. This damage is of only a temporary nature, since autumnal rains initiate regrowth of tussock and annual species shortly after the birds leave. Such short-term changes in the rookery vegetation are not necessarily disadvantageous to the burrowing species. Whilst during the breeding season destruction appears remarkably complete, the overwinter recovery is sufficient to maintain the simplified, though possibly specialized, ecosystem and to preserve a status quo in which the damaged tussock is invaded by ephemerals and ruderals such as *Senecio* or *P. annua* before the tussock can seed and regenerate (see also Gillham 1960b). Such destruction may, however, assume greater importance when the rookery vegetation is also subjected to intensive grazing by rabbits in a dry year; the stress applied to the vegetation would, at this time, be directly related to the size of the rabbit population. That this may become high is indicated by estimates of between 150 and 200 rabbits on Motunau Island, N.Z. (Taylor, in Burton 1967), which is only nine acres overall.

In the drier summer periods, and in dry years, the grazing and scratching for roots would tend to suppress expansion of existing communities and to prevent seedling growth. In the presence of high rabbit populations the localized erosion, present under normal conditions in muttonbird rookeries, can become accentuated. Burrows, or initially their entrances, are known to be centres of erosion (Gillham 1956) and wind and rain can act on the bared area around the burrow. Since the birds themselves cause localized destruction (see above) and also break root systems as they burrow, there is an increasing lack of stabilization in dense nesting areas as the season advances. Guano deposition would also aid the process of destruction (Gillham 1960a), particularly in years of low rainfall. In consequence, small areas of erosion would in time coalesce, eventually forming the sand blow. On Rabbit Island the process has not taken long; clearing of the island is presumed to have started prior to 1846 (when Haydon recorded the presence of a hut and garden on the island) and to have been assisted by fires, some of which have swept the island in recent time (Norman 1967). None the less, Citadel Island has suffered a more complete destruction (Gillham 1962) in a shorter period since rabbits were first introduced there in 1913. Acceleration of erosion on both islands may have resulted, and almost certainly has done on Rabbit Island, from the instability of a soil which is mainly sand. The central region on Rabbit Island (assumed to have been colonized by birds and *Poa* after clearing) is likely to have had an unstable equilibrium set up between burrowing birds and rabbit grazing, and one considerably less stable than within the longer established rookeries along the coast. Removal of the rabbit population led immediately to a decrease in the grazing pressure and an increase in the species total. This was then followed by colonization by *Poa* seedlings.

Such a rapid colonization, following removal of grazing pressure, has been assisted by several factors favourable to regeneration of the flora. *Poa* seeding has undoubtedly been achieved from the stands at either end of the island, and the Promontory has probably acted as a seed supply for other seedlings. The presence of a reasonable depth of soil, and nutrients from bird faeces, probably enabled establishment to take place rapidly; in areas of minimal soil, succession would take considerably longer. Further, regrowth in the area is assisted by the relatively high rainfall of about 40", and even more importantly, by the mean monthly relative humidity in the area which, as recorded at Wilsons Promontory, remains above 75 per cent throughout the year (Bureau of Meteorology 1956).

Since the sand blow crossed an area previously colonized by muttonbirds, the effect of vegetation degradation, aided by the rabbit, has been serious in relation

to the island population of birds. The eroded area initially covered 16 acres (0.07 km square), 20 per cent of the island's total; if the whole island had been densely burrowed (a dense colony would have approximately four burrows per square yd) then over 300,000 burrows would have been destroyed during erosion. That the birds are unable to maintain burrows in pure sand was indicated by results of transects through three portions of rookery; both the number of burrows and the total remaining open were at a maximum in stabilized sand. Burrows in pure sand were fewer and more were collapsed.

I suggested earlier (Norman 1967) that erosion of the central region of the island had followed the introduction of the rabbit and the clearing and burning of the vegetation, and that removal of the rabbit would enable a regrowth to take place across the area once occupied by the birds. Revegetation since the start of the programme has certainly stabilized the area to the extent that muttonbirds have invaded the area to nest. It is probable that further expansion of the rookery area will continue as the soil becomes increasingly stable and deeper. At present across the central ridge nesting is limited by lack of adequate soil depth.

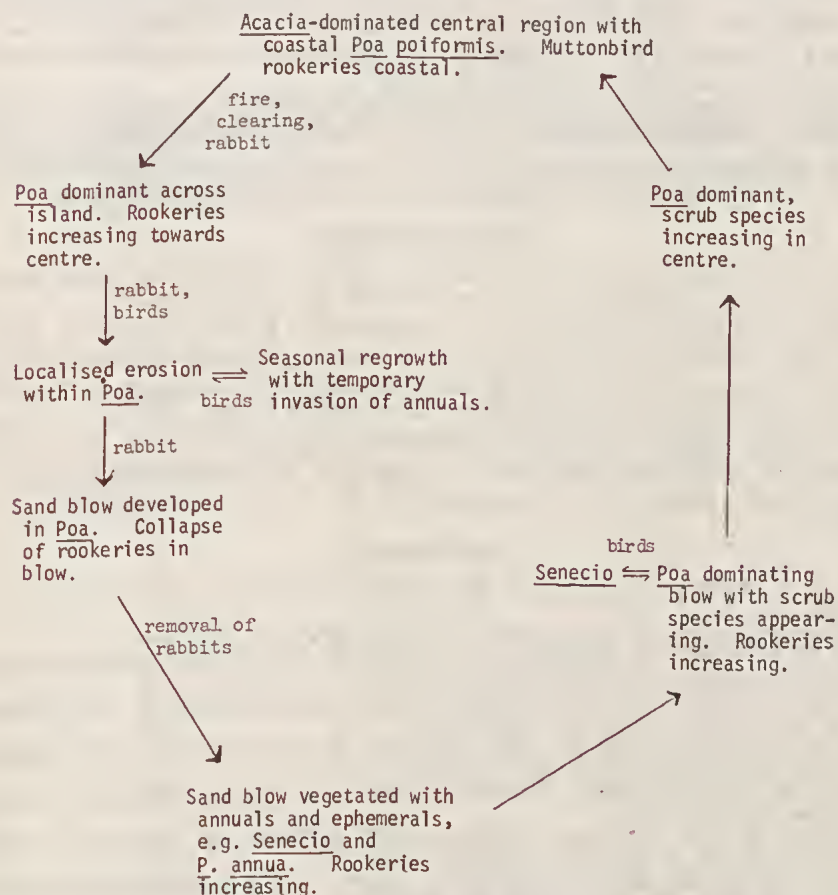


FIG. 11—Schematic representation of changes in the island's vegetation with respect to the sand blow region and to the distribution of muttonbird rookeries.

Conclusion

During this part of the study, I have been examining the effects of rabbits on muttonbirds. It has not been possible to examine direct effects, in the nature of burrow utilization, conflict for burrows, etc. However, these problems are secondary to the effect of the rabbit on the habitat in which the muttonbird burrows and breeds. Primarily the rabbits are considered to affect muttonbirds indirectly. Their selective feeding and scratching has added to the erosion which is normal, at a low level, within the rookeries. The equilibrium of destruction and regeneration present in the rookery habitat is displaced by this additional pressure to the extent that complete denudation of cover occurs. Decreasing soil stability in a region of exposed sand soil leads to widespread erosion. The end result at Rabbit Island was a division of a homogeneous rookery into two discrete parts, separated by a large eroded area. In destroying the vegetation the rabbits contributed largely to a situation where birds were unable to maintain nesting burrows in the sandy soil. Progressive decrease in the rabbit population has initiated a regeneration process which has reversed the degeneration of habitat to the extent that birds are recolonizing old breeding areas. This could have arisen from a redistribution of birds using other rookery areas on the island or by an addition to the total breeding population. The latter seems more likely since muttonbirds generally do not change their nesting sites (Serventy 1967).

A scheme summarizing suggested changes in the island's vegetation and muttonbird rookery distribution is given in Fig. 11. The cycle of vegetational degeneration and subsequent regeneration following the removal of rabbits is presented, together with the main factors considered to be operating at each stage.

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Description of Plate

PLATE 23

- TOP—View from fixed peg towards trigonometric point across previously denuded area, August 1966.
- BOTTOM—Run-off stream in south-western corner of sand beach, 1966. Note that vegetation has not regenerated.